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FISHERY MANAGEMENT STUDIES ON MADISON RIVER SYSTEM IN YELLOWSTONE NATIONAL PARK

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FISHERY MANAGEMENT STUDIES ON THE MADISON RIVER SYSTEM IN YELLOWSTONE NATIONAL PARK

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ABSTRACT

Research to appraise current fish management practices and to develop improved practices was carried on in the Yellowstone National Park portion of the Madison River system from 1953 to 1957. The physical, chemical and biological characteristics of the Firehole, Gibbon and Madison Rivers are described.

Experiments designed to test the value of fingerling and adult stocking resulted in the conclusion that fingerling stocking of brown and rainbow trout does not contribute to the fishery substantially and that adult stocking is of greatest value only in the season of stocking. Examination of scales showed that hatchery fish are readily distinguishable from wild fish. There were no differences in growth rates of wild fish in different years for different rates of stocking of hatchery fish. The brown and rainbow trout populations are not affected adversely by heavy introduction of hatchery fingerlings of each species or of adult rainbows. Brook and brown trout and whitefish are substantially underfished.

FISHERY MANAGEMENT STUDIES ON THE MADISON RIVER SYSTEM IN YELLOWSTONE NATIONAL PARK

The Madison River drainage in Yellowstone National Park includes the Madison, Firehole, and Gibbon Rivers (fig. 1) and has had a reputation for providing some of the best trout fishing in the western United States. It is part of the Missouri River Basin. The brown trout (Salmo trutta) of the Madison and lower Gibbon have achieved nationwide fame because of their large size, and brown trout of the Firehole River are well-known because of their abundance. The postwar increase in number of tourists in Yellowstone focused additional attention on this stream system, and the Fish and Wildlife Service was consulted in 1951 regarding two problems in the Firehole and Madison Rivers. One problem concerned the advisability of continuing the planting of brown trout in the Firehole; the other pertained to the tremendous upsurge in fishing pressure anticipated for the next 10 or 15 years.

Biological field investigations began in 1953 on the Madison, Firehole, and Gibbon Rivers and were terminated in 1957. The studies consisted of a creel census to learn the characteristics of the catch and of the fishermen, marking a large proportion of fish planted under the regular planting schedule, recovery of marked fish in the fishery, studies of scales of wild and hatchery fish, and electric shocking to determine the sizes and compositions of the populations.

ACKNOWLEDGMENTS

Mr. Harry Baker, Superintendent, U.S. Fish Cultural Station, Ennis, Montana, and Mr. Lloyd Justus, Superintendent, U.S. Fish Cultural Station, Bozeman, Montana, gave invaluable help by providing fish for marking and planting, by making the facilities of their hatcheries available, and by providing personnel to help in the marking and handling of fish.

National Park Service personnel who cooperated and assisted in various ways were Edmund Rogers, formerly Superintendent, Yellowstone National Park; Lemuel Garrison, the present Superintendent; Carl Gilbert, Frank Anderson, and Les Gunzel, District Rangers; Walter Kittams, Park Biologist; and several rangers.

Special thanks are due Mr. Joseph Chennault and Dr. William Sigler for the loan of the electrical seine, and to Mr. Lynn Peterson of the Homelite Company for the loan of the generator.

Fish and Wildlife Service personnel who had important parts in the planning and execution of the work were Orville P. Ball, Jr., and Martin Laakso, Fishery Research Biologists.

MANAGEMENT HISTORY

The management of fish populations in the Madison River drainage in Yellowstone began in 1889, when rainbow trout (Salmo gairdneri) were planted in the Gibbon River above Virginia Cascades and brown trout were planted in the Firehole River above Kepler Cascades. Prior to that time, the Firehole River above Firehole Falls and the Gibbon River above Gibbon Falls were barren of fish. The Madison River had populations of cutthroat trout (Salmo clarki), whitefish (Prosopium williamsoni), and grayling (Thymallus signifer), as did the Gibbon River in the six-mile section below Gibbon Falls and the Firehole River in the four-mile section below the falls.

Stocking of fish continued to be the primary management procedure in this drainage for many years. Additional plantings of brown trout were made in the Firehole River and its tributaries, and rainbow and brook trout (Salvelinus fontinalis) were also stocked in this stream. Rainbow and brook trout were added to other sections of the Gibbon River, and in 1907 rainbow were planted in Grebe Lake, followed by cutthroat in 1912. By that time, the Madison contained cutthroat, brown, rainbow, and brook trouts, as well as whitefish and grayling. Grayling were introduced into Grebe Lake in 1921, and have thrived there. Various stocking practices were used after that time, and natural adjustments were made by the fish themselves through upstream and downstream

Table 1.--Partial chemical composition in ppm. of water from Firehole River at Old Faithful and one-half mile above mouth of Nez Perce Creek on July 29, 1958. Analyses by U. S. Geological Survey.

Constituents	Old Faithful, 1958	Nez Perce, 1958
Silica (SiO_2)	46.0	101.0
Iron (Fe)	.04	.03
Calcium (Ca)	3.5	4.6
Magnesium (Mg)	0.3	0.6
Sodium (Na)	13.0	86.0
Potassium (K)	3.4	7.3
Bicarbonate (HCO_3)	25.0	130.0
Sulfate (SO_4)	5.3	17.0
Chloride (Cl)	11.0	71.0
Fluoride (F)	2.0	6.6
Nitrate (NO_3)	0.1	0.3
Boron (B)	0.14	0.81
Dissolved solids	100.0	387.0
Alkalinity as $CaCO_3$	21.0	115.0
Specific conductance (micromhos at 25° C.)	99.1	519.0
pH	6.7	7.8

Water temperatures were recorded during the summer of 1950 and May, 1951, by Armitage (1954) at five points from Lone Star Geyser to the junction of Nez Perce Creek. The maximum temperatures recorded were as follows: May, Lone Star - 50° F., Nez Perce - 68° F.; June, Lone Star - 54° F., Nez Perce - 69° F.; July, Lone Star - 57° F., Nez Perce - 70° F.; August, Lone Star - 57° F., Nez Perce - 73° F.; and September, Lone Star - 54° F., Nez Perce - 66° F.

The standing crop of riffle bottom fauna increased downstream with increasing total solids and alkalinity. Armitage found the following total weights of organisms per square foot in milligrams: Riverside Geyser (Upper Geyser Basin), 4,303.48; above Biscuit Basin (lower part of Upper Geyser Basin), 10,613.86; Midway Geyser Basin, 13,026.25; and below the junction of Nez Perce Creek, 9,608.15. The most abundant organisms collected were Hydropsyche, which was in the faster currents, and Brachycentrus, which was found in the slower sections.

Only brook, brown and rainbow trouts exist above Firehole Falls, while northern mottled sculpins (Cottus b. bairdi) and longnose dace (Rhinichthys c. cataractae) are abundant below Firehole Falls. Whitefish are present in the lowest one mile of stream.

Madison River

The Madison River flows 25 miles within Yellowstone National Park with an average gradient of about eight feet per mile. It meanders through meadow areas. Some sections consist of wide, shallow riffles, while other parts of the stream contain deep holes. Large aquatic plant beds are present and the bottom fauna production is high. The monthly mean water flow from October, 1952, to September, 1956, varied from 340 to 1,212 cfs. 1/ The water flow was fairly constant from November through March (340-452 cfs.), began to rise in April (396-539 cfs), reached its maximum in May and June (719-1,212 cfs.), and declined to the lowest flows during September and October (298-449 cfs.). The mean annual water volume for 39 years (periods from 1913 to 1955) was 341,700 acre feet.

1/ Data on water flows taken from U. S. Geological Survey Water Supply Papers.

movement and through hybridization. The present distribution of species in these streams and their tributaries is Madison River - brown and rainbow trout, whitefish, and very few grayling and brook trout; Firehole River - brown and rainbow trout, and some brook trout in certain sections; Gibbon River - grayling and hybrid trout (rainbow x cutthroat) in Grebe and Wolf Lakes and in smaller numbers downstream, brook trout and rainbow trout in the middle section of the stream, and brown and rainbow trout below Gibbon Falls.

During the period from 1948 to 1952 the average annual plants in this system were:

Madison River - 66,800 trout (brown fingerlings, and rainbow adults).

Firehole River - 74,240 trout (brown and rainbow fingerlings).

Gibbon River - 11,000 brown trout fingerlings.

Management of these fish populations began with few restrictions on the angler. In 1942 the fishing season extended from May 30 to October 15 in the Firehole and Gibbon Rivers, and from May 30 to September 30 in the Madison River. The daily limit of catch was 15 pounds plus one fish, not to exceed ten fish per person. In 1946 the daily catch limit was changed to five fish per person per day for the Madison River, the Firehole River below Kepler Cascades, and the Gibbon River below Gibbon Falls. Subsequently, the entire Gibbon River was placed under the same restriction, as was the Firehole River above Kepler Cascades. In 1949 the use of fish eggs for bait was prohibited in the park. In 1950 a bait restriction was put into effect on the Madison and Firehole Rivers; only artificial flies with a single hook could be used by fishermen, and no other lures. The Gibbon River below Gibbon Falls was put under the same restriction in 1951. No minimum size limits exist on the Madison River system.

DESCRIPTIONS OF STREAMS

Firehole River

The Firehole River originates in Madison Lake, located about eight miles south of Old Faithful, and flows northward for about 32 miles where it joins the Gibbon River (fig. 1). The flow in early September 1957 was about 35 cfs. at Old Faithful and about 200 cfs. where it joins the Gibbon. Many hot springs and geysers enter the river along a 12-mile section below Old Faithful. The river falls about 700 feet from two miles above Old Faithful to its mouth, an average gradient of 28.2 feet per mile. It varies in width from 40 to 100 feet and in depth from six inches to over ten feet. Firehole Falls are 40 feet high and are located about four miles above the stream mouth; for the next two miles below the falls, the Firehole flows through a gorge in a series of cascades. The falls, together with the cascades, serves as a barrier against upstream fish movement.

The chemistry of the water in the Firehole River is variable because it is influenced by periodic eruptions of geysers. Water was collected from Old Faithful and from above the mouth of Nez Perce in 1958 and analyzed by the U.S. Geological Survey (table 1). Several ions, particularly silica, bicarbonate, sodium, and chlorides, increased greatly as a result of geyser activity.

The temperature of the water in the Firehole is influenced to some degree by geysers, but only localized areas become too warm for brown and rainbow trout. Simonian (1952) recorded the influence of Giant Geyser, the largest geyser in the park, on the temperature of the Firehole River. Water temperatures 200 yards downstream from the eruption rose from 64°F. to 75°F. At the point where the thermal water was entering the stream, a temperature of 115°F. was recorded. Giant Geyser erupts irregularly with a minimum interval of 48 hours, and the temporary influence of the warm water does not prevent brown and rainbow trout from living under such conditions. The distribution of the brook trout in the Firehole was outside of the areas influenced by thermal activity; they were principally confined to small tributary streams and to areas above Old Faithful.

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1/ Data on water flows taken from U. S. Geological Survey Water Supply Papers.

Water temperatures during the summer vary from 60° F. to the low seventies. Winter water temperatures were collected in 1955 and showed 32° F. on several days. Anchor ice commonly formed on riffles.

The fish population consists of large numbers of brown and rainbow trout, whitefish, northern mottled sculpins, and longnose dace. The longnose sucker (Catostomus catostomus) is present, but rare. Cutthroat trout have been reported but were not observed by our creel census clerks or by electric shocking.

Gibbon River

Gibbon River originates in Grebe Lake and flows about 24 miles to Madison Junction where it joins the Firehole (figure 1). The stream drops about 1,100 feet for an average gradient of 44 feet per mile. Three falls, which serve as barriers to upstream fish movement, account for a total drop of 169 feet: Little Gibbon Falls drops 25 feet, Virginia Cascades drops 60 feet, and Gibbon Falls drops 84 feet.

Temperatures in the Gibbon River have never been recorded above 64° F., and it is doubtful if they ever reach 70° F. A few hot springs enter the Gibbon near its mouth and many at Norris Geyser Basin, but the water is probably softer than the Firehole since the conductivity of the Madison was lower (312 mhos.) than the Firehole (385 mhos.) and the dilution by the Gibbon must have caused this condition.

Above Virginia Cascades, the stream is populated with small (3-6 inch) brook trout and grayling. Woodbury (1930) reported rainbow trout but none have been observed recently. The section of stream between Virginia Cascades and Gibbon Falls contains brook trout, grayling, sculpins, and longnose dace. Rainbow trout have been stocked but have not been observed commonly. Below Gibbon Falls rainbow and brown trout are present, in addition to sculpins and longnose dace.

METHODS

Creel census

The creel census used on the Madison River system from 1953 to 1957 was designed to estimate the total fishing pressure and catch. Three men were used on the census of the three rivers from 1953 to 1956; in 1957 two men were used on the Madison and Firehole and no data were collected on the Gibbon. All data were grouped for analysis into two-week periods and into stream census areas (e.g., M-1, M-2, on figure 1). The creel census consisted of fisherman interviews and fisherman counts. Interviews were conducted on five 8-hour days the entire length of each stream during each period. All fishing hours were sampled. Information was collected on location of fishing, date, completed or incompleted trip, and number of fish caught by species. Scale samples were taken from all fish collected from 1954 to 1957.

Fisherman counts were made five days during each period on each stream. All streams are close to roads and accurate counts were possible. Working hours were scheduled to sample all hours of fishing, and complete counts were made six or eight times each working day. We assumed that each angler observed accounted for one hour of fishing. The total fishing pressure by hours for each period was computed by multiplying the average number of fishermen observed for each hour by the number of fishing hours during the period. The total catch was computed by multiplying the catch per hour by the number of fishing hours. The number of fishing trips was computed by dividing the average length of each completed trip by the estimated number of fishing hours each period.

Experimental stocking

The same stocking program as followed in recent years was followed in this study since it was necessary to determine its value to anglers. Originally, this study involved the marking of a percentage of the planted fish (both fingerlings and adults) prior to planting, and the checking of creels to determine the number of these fish that entered the catch. The marking

of fish was carried out at U. S. Fish and Wildlife Service hatcheries in Ennis and Bozeman, Montana, during 1954 and 1955. All marking was done by clipping various combinations of fins.

It was assumed at the beginning of this investigation that among adult fish (above eight inches) the ratio of unmarked fish to marked fish in the fishermen's catch would be the same as the ratio of unmarked to marked fish in the plantings. This assumption was proved invalid from examination of scale samples collected by creel census clerks. The scales of planted hatchery fish over eight inches can be easily distinguished from scales of wild fish of the same size group. Growth under hatchery conditions is more regular and no clear annuli are formed (figure 2). The ratios of marked to unmarked hatchery fish in the creel in 1954 was 1:1.10, while the ratio of marked to unmarked hatchery fish in the plantings was 1:2.6. In 1955 the ratio of marked hatchery fish to unmarked hatchery fish in the catch was 1:1.57, while the ratio in the planting was 1:3.125. Therefore, we decided to distinguish hatchery fish from wild fish by the scale method only for final analyses of recovery rates.

All fish were marked from one to six weeks prior to actual planting. A check was made of regeneration of fins which might occur, especially in the fingerling fish. On the fingerling plants, there were differences in the amount of regeneration among individual lots of fish. The anals and ventrals showed marked regeneration in many cases. The pectorals showed the least regeneration, and the dorsals showed a moderate amount of regeneration. Creel census clerks were instructed to carefully check all fins on the fish examined and it was usually possible to discern the original mark on a regenerated fin since regenerated fin rays grow differently from normal fin rays. Therefore, regeneration would not upset the accuracy of the fingerling recovery estimate data since only returns checked by clerks were used in the calculations.

There is a possibility that unmarked fingerlings might survive better than marked fingerlings. Cooper (1953a) found essentially the same survival rates in unmarked and marked brook and brown trout. Cope and Slater (1957) summarized several papers on possible different survival rates between unmarked and marked fingerling salmon and considered this factor as a possible error in their recovery rate estimates. In the present study, the trout fingerlings were retained in the hatchery for several weeks after marking and any definite mortality trend would have been observed before planting. As shown later, the results of the study would not have been significantly changed, even if the mortality rates of the marked fingerlings were 100 percent greater than those of the unmarked fingerlings.

Age and growth

Most of the scale samples (1,273) used in determining age and growth of brown and rainbow trout and whitefish were obtained from fishermen's creels in conjunction with the creel census from 1953 to 1957. A few (36) scale samples from small browns and rainbows were collected in 1957 with an electric shocker. The clerks measured the total length of each fish to the nearest five millimeters or to the nearest one-tenth of an inch. Scales were collected from the fish on the body area below the dorsal fin and midway between the lateral line and the mid-dorsal line of the fish. Scales were mounted in sodium silicate and read on a standard scale microprojector.

The samples of scales collected did not contain enough small fish for determination of accurate body-scale relationships. Regressions of body length to anterior scale radius were plotted and calculated by solution of simultaneous equations. Our plotted data showed that linear relationships were sufficiently accurate for practical purposes. Back calculations were made with a straight-line nomograph, using the Y intercept determined from the regression analyses.

Fish populations

Studies on fish populations were made from September 3 through September 13, 1957, on the Firehole and Madison Rivers with electrical shocking equipment. No population data were collected from the Gibbon River.

On the upper Firehole River (Stations A and B on figure 1), a 220-volt A.C. electric

Scale of wild rainbow trout in its second year of growth, captured in Madison River on September 1, 1955. Trout was 8.0 inches in total length. The distinct annulus half way out on the scale is typical of all wild rainbow scales examined.

Scale of marked rainbow trout planted in Madison River in 1955 from Ennis Hatchery. Trout was 13.0 inches in total length at capture on June 15, 1955, and had been in the stream only a few days.

Figure 2.--Scales of wild and hatchery rainbow trout showing differences in circulus patterns.

shocker was used with paddle-type electrodes; downstream an electric seine was used. A five-man crew shocked through each sampling station (200 yards of stream) twice. On the first trip all fish were measured to the nearest inch, marked by clipping a small portion of the caudal fin, and released in the water in close proximity to where they were collected. On the second trip, which was made within one-half hour of the first, data were collected on the number of marked and unmarked fish by inch groups. The total population was calculated from the assumption that marked and unmarked trout were captured in the second run in direct proportion to their numbers in the stream. Since large trout were collected more easily than small ones, it was necessary to make separate estimates for different size groups. There were no significant differences in recovery rates between rainbow and brown trout of the same size range; therefore, the average recovery rates of both species were used to compute the population estimates when too few trout could be collected within a size group. The recovery rates of both brown and rainbow trout by size groups were as follows: 2.0 to 4.9 inches, 10.6 percent; 5.0 to 8.9 inches, 15.0 percent; and 12.0 to 21 inches, 30.7 percent. No block seines were used to restrict the movement of fish out of the sample area although the fact that the second trip was made within one-half hour of the first would minimize such a cause for error.

The lower part of the Firehole (below Station B) and the entire Madison River were too large for the equipment and the sampling method described above. Each sample area was shocked once and a 60-foot electric seine with a pulsating D.C.-A.C. current was used to collect fish. The information collected was limited to gaining a general knowledge of the size and structure of the fish population. The electric seine was effective in stunning fish of all size groups, although the crew could collect only a small percentage of the fish actually observed. Most fish collected were measured to the nearest inch and then released. Rainbow and brown trout were the two most common species collected, and it is believed that this sampling method collected both species at about the same rate. Whitefish were more difficult to collect than brown or rainbow trout because they were located in deep holes.

The age class composition of the brown trout population was determined from aging studies of fish caught by anglers during the 1957 fishing season and from 36 fish below 8.0 inches captured by shocking. The 36 small trout were all collected from the Madison, and the data were applied to both the Madison and Firehole Rivers. This method was considered reliable since growth rate studies showed that small brown trout grow at about the same rates in both the Firehole and the Madison. When several age groups were represented within a single inch group, the percentage of each age group was determined. For example, within the 8.0 to 8.9 inch group on the Firehole River, 76.9 percent were Age Class I and 23.1 percent were Age Class II. With this information it was possible to convert all population data by one-inch groups into the age class composition of the population. All trout and whitefish above 8.0 inches were considered to be catchable-size to the angler.

FISHING PRESSURE AND CATCH

Fishing pressure

The number of fishermen on the Madison River system from 1953 to 1957 was: 1953, 19,504; 1954, 27,233; 1955, 23,477; 1956, 24,293; and 1957, 25,599 (not including Gibbon) (table 2). The average annual number of trips per mile of stream from 1953 to 1957 was: Madison, 425; Firehole, 382; and Gibbon, 199 (not including 1957). The Madison and Firehole have been attracting more fishermen in recent years, while the Gibbon has been attracting fewer. The fishing pressure, as measured by the total hours of fishing effort, increased in the Madison from 1953 to 1955 and decreased in 1956 and 1957 (figure 3). This decrease apparently was due to decreased planting of adult rainbow trout. Fishing pressure on the Firehole increased from 13,904 hours in 1953 to 34,460 hours in 1956 and decreased to 22,974 hours in 1957. The Gibbon retained a relatively constant effort from 1953 to 1956, with a range of 8,401 to 10,861 hours. The fishing pressure during each season on all streams showed a peak in early July; subsequently, fishing pressure showed a gradual decline to the end of the fishing season. The peak in July was probably related to the heavy influx of tourists into the park during the July 4 weekend and from the fact that stream fish become more difficult

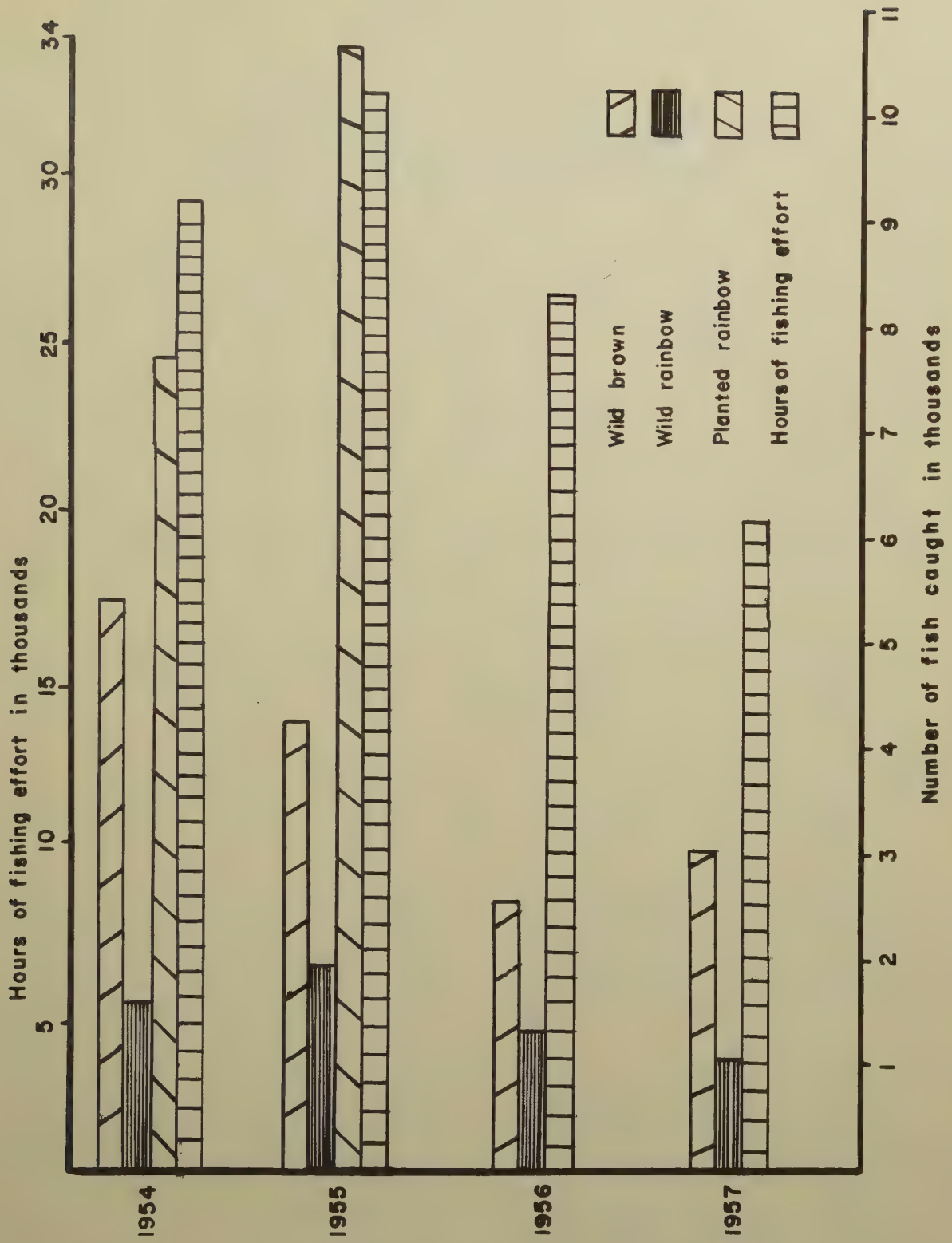

Figure 3.--Catch of wild brown, wild rainbow, and planted adult rainbow trouts in the Madison River from 1954 to 1957. Hours of fishing effort are included for comparison with catch.

Table 2.--Total number of fishermen, total hours of angling effort, total catch of fish, and catch per man hour on Firehole and Madison Rivers from 1953 to 1957 and on Gibbon River from 1953 to 1956.

	Year of census				
	1953	1954	1955	1956	1957
Number of fishermen					
Firehole	7,535	9,663	7,059	11,487	11,662
Madison	6,422	11,925	12,467	8,857	13,937
Gibbon	5,547	5,645	3,951	3,949	—
Hours of effort					
Firehole	13,904	19,932	18,806	34,460	22,974
Madison	15,756	29,358	32,584	26,571	19,651
Gibbon	9,248	8,597	8,401	10,861	—
Total catch of fish					
Firehole	4,219	6,688	9,955	5,831	5,876
Madison	6,219	15,557	18,025	4,159	4,685
Gibbon	2,078	3,078	4,503	1,743	—
Catch per man hour					
Firehole	0.303	0.337	0.529	0.169	0.256
Madison	0.395	0.530	0.553	0.157	0.238
Gibbon	0.225	0.358	0.536	0.160	—

to catch during late summer. The planting of adult rainbows in 1954 and 1955 from June 13 to July 24 was also partly responsible for the increase in pressure during early July in the Madison and the lower Gibbon.

Rainbow trout catch

The Firehole was never stocked with adult rainbows and the catch has represented almost entirely wild fish (table 3). The catch of wild rainbow was: 1954, 2,199; 1955, 4,007; 1956, 2,204; and 1957, 1,946. The rainbow trout fishery in the Madison River has changed due to changes in planting procedures. The wild rainbow trout fishery in the Madison remained relatively stable from 1954 to 1957, with catches as follows: 1954, 1,643; 1955, 1,972; 1956, 1,301; and 1957, 1,040 (figure 3). The catch of hatchery fish increased in direct proportion to the size of the planted fish. In 1954, 25,006 eight-to-ten-inch rainbow trout were planted and the catch was 7,705 fish. In 1955, 21,687 ten-to-twelve-inch rainbow trout were planted and the catch was 10,663 fish. The rainbow trout fishery in the Gibbon was essentially restricted to G-1, below Gibbon Falls. Many hatchery fish stocked in the Madison in 1954 were caught in this section of the Gibbon. The plantings in 1955 were made both in the Gibbon and the Madison. The rainbow fishery in the Gibbon in 1954 and 1955 consisted mostly of these plants and only 395 were caught in 1956 when no plantings were made.

Brown trout catch

The brown trout catch has been completely from wild stock. The catch in the Firehole ranged from 2,927 in 1953 to 5,615 in 1955 (table 3). There was a negative coefficient of correlation of 0.124 between the fishing pressure by hours and

Table 3.--Estimated catch of wild and hatchery fish from Firehole and Madison Rivers from 1953 to 1957, and from Gibbon River from 1953 to 1956.

Fish species and river	1953[1]	1954		1955		1956[2]	1957[2]
	Wild and hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Wild
Firehole							
Rainbow	1,202	2,199	75	4,007	104	2,204	1,946
Brown	2,927	4,260	0	5,615	0	3,605	3,467
Whitefish	10	0	0	50	0	11	0
Brook	80	127	0	179	0	11	463
Grayling	0	27	0	0	0	0	0
Total	4,219	6,613	75	9,851	104	5,831	5,876
Madison							
Rainbow	2,647	1,643	7,705	1,972	10,663	1,301	1,040
Brown	3,321	5,434	0	4,254	0	2,522	3,017
Whitefish	193	620	0	1,082	0	258	511
Brook	29	155	0	54	0	56	47
Grayling	29	0	0	0	0	22	70
Total	6,219	7,852	7,705	7,362	10,663	4,159	4,685
Gibbon							
Rainbow	715	360	350	536	2,309	395	
Brown	925	1,241	0	1,162	0	490	No
Brook	405	1,099	0	464	0	776	census
Grayling	33	28	0	32	0	82	
Total	2,078	2,728	350	2,194	2,309	1,743	

1/ It was not possible to distinguish wild from hatchery fish because only a few scales were collected.

2/ No hatchery fish were recorded caught in 1956 or 1957 by our creel census clerks.

total catch during the five years of census. In the Madison River the catch showed a positive coefficient of correlation of 0.554 with the total fishing effort. The data on the Madison indicated that the heavier fishing pressure caused by the stocking of adult rainbow trout caused a heavier harvest of the brown trout. The small brown trout fishery in the Gibbon also showeda positive relationship between the catch by year and the amount of fishing effort.

Catch of other species

Brook trout do not grow large enough to be attractive to most anglers in these streams. Those caught in the Firehole are taken from above Old Faithful or from small tributary streams. The Gibbon has the largest population and they made up 44.5 percent of the fish catch in 1956. The few brook trout caught in the Madison River were probably migrants from the Gibbon.

Whitefish assume importance in the creel only in the Madison River where the catch ranged from 153 in 1953 to 1,082 in 1955 (table 3). Whitefish inhabit deep turbulent water which is difficult to fish and are not caught in numbers in relation to their abundance.

Grayling are abundant in the upper Gibbon, but never made up over 4.7 percent of the catch in this stream. The few caught in the Madison and Firehole were probably migrants from the Gibbon.

FINGERLING TROUT PLANTING

Plantings of fingerling rainbow trout in 1954 and 1955 contributed little to the catch in 1955 and none was recorded as caught in 1956 or 1957 (table 4). The plantings of fingerling rainbows in the Firehole entered the fishery in greater numbers than did those plantings in the Madison and Gibbon, but only 0.29 percent entered the catch. Some of the 1954 plantings in the Firehole moved downstream and all recoveries made were from the Madison. The average recovery rate of all planted rainbow fingerlings was 0.16 percent. Fingerling rain-

Table 4. Returns of marked fingerling (3-5 inches) plantings of brown and rainbow trout to the fishermen's creel in Madison, Firehole, and Gibbon Rivers, 1954-1955.

Stream	Species	Number planted	Date planted	Estimated number caught		
				1955	1956	1957
Madison	Rainbow	10,083	10-14-54	9	0	0
Firehole	Rainbow	10,017	6-21-54	46[1/]	0	0
Firehole	Brown	10,000	6-28-54	0	0	0
Madison	Rainbow	10,002	5-23-55	9	0	0
Firehole	Brown	10,249	5-17-55	0	0	0
Firehole	Rainbow	10,114	5-24-55	14[2/]	0	0
Gibbon	Rainbow	8,000	5-23-55	0	0	0
Totals:	Rainbow,	48,216; estimated number caught, 78 (0.16%)				
	Brown,	20,249; estimated number caught, 0				

1/ All caught in Madison

2/ All caught in Firehole

bow were stocked both in October and during May and June and no great differences in recovery rates were noted. Other similar experiments have found that "in-season" plants were more successful than fall plantings, but it was thought that the thermal water entering the Madison might possibly lower the winter mortality rate on fingerlings planted in October.

None of the brown trout fingerlings planted were recorded as entering the creel. Westerman and Hazzard (1945) summarized the results of fingerling trout stocking experiments in Michigan and three other states. In 12 experiments with rainbow trout, an average of 2.02 percent reached the fishermen's creel. From five experiments with brown trout, 3.4 percent reached the fishermen's creel. They concluded that streams with adequate natural reproduction usually cannot grow any more fingerlings to catchable size than are produced naturally. Schuck (1948) summarized much of the literature on trout stocking and restated the low survival rate of planted brown trout fingerlings. We must conclude that the fingerling stocking of brown and rainbows in the Madison River system did not contribute measurably to the fishermen's creel.

ADULT RAINBOW TROUT PLANTING

Adult rainbow trout planted in the Madison River in 1954 and in the Madison and Gibbon in 1955 contributed greatly to the catch; of the 49,798 planted, 21,128 were caught by fishermen (table 5). The return of the 25,006 fish planted in 1954 was 33.2 percent, while the return of 24,792 fish planted in 1955 was 51.7 percent. The increase in recovery in the plantings of 1955 over 1954 was probably due to the fact that the trout stocked in 1955 were ten to 12 inches while those stocked in 1954 were eight to ten inches. The anglers' catch showed a low survival rate of adult rainbow trout to the year following planting. A few (170) of the 1954 plantings were caught in 1955, but none of the 1955 plantings were recorded as caught in 1956 or 1957.

The results of this study agree closely with other investigations in the United States on return of planted adult rainbow trout to the angler. The State of California (1951), after several years of study, rejected the policy of stocking catchable-sized trout in any waters unless anglers could catch at least 50 percent of those planted. Cooper (1953b) found that rainbow trout in Michigan planted during the angling season at accessible points should give a return in excess of 67 percent. King and Holloway (1952) mentioned recovery rates of 53 and 90 percent in Tennessee. Recovery rates on stocked rainbow trout in the Logan River, Utah, were above 80 percent if they were planted during the fishing season (Regenthal, 1952). None of the studies considers the carryover to the year following planting to be significant. In short, their value to the fishermen is greatest when they are planted virtually "in front of the rod."

There was both upstream and downstream movement of adult rainbow trout following planting. Most catches were made, however, within five miles of the location of plantings, and no hatchery fish were recorded caught outside of Yellowstone National Park. An organized program was conducted in 1955 to determine the presence or absence of marked adult rainbow in Hebgen Reservoir, one mile downstream from Yellowstone Park. More than 1,000 trout were examined by creel census personnel and boat dock operators, and no trout with Madison River marks were found.

FISH POPULATIONS

Firehole River

The Firehole River above Midway Geyser Basin was populated principally by brown trout, although a few catchable-size rainbows were present (table 6). Most fish (91.8 percent) were young-of-the-year brown trout. At Riverside Geyser there were an estimated 528 catchable-size brown trout per mile of stream; at Biscuit Basin there were 597. These populations of catchable-size fish were much higher than were reported in Minnesota (Smith, et al, 1949) or in Michigan (Shetter and Hazzard, 1939). The age class composition of the brown trout population as determined from data in table 7 in the six miles of stream below Old Faithful was: 0, 21,824; I, 1,084; II, 407; III, 213; IV, 96; and V, 129 (table 8).

Table 5.--Estimated returns of planted adult rainbow trout to the fishermen from the Madison River in 1954 and from the Madison and Gibbon in 1955. Number of fish caught includes those caught in Madison, Gibbon 1, and Firehole 1.

Plantings				Number of fish caught				
Stream	Dates	Number	Total length in inches	1954	1955	1956 and 1957	All years	Percentage recovery
Madison	6-15 to 7-17, 1954	25,006	8-10	8,130	170	0	8,300	33.2
Madison and Gibbon	6-13 to 7-24, 1955	24, 792	10-12	--	12, 828	0	12, 828	51.7
Total		49, 798		8, 130	12, 998	0	21, 128	42.4

Below Biscuit Basin in the Firehole River both brown and rainbow trout were common at all stations sampled, although reliable estimates of the total populations could not be made. A total of 1,062 catchable-size brown trout and 103 catchable-size rainbow trout were collected per mile of stream at all seven stations. Age Class 0 brown trout were also present in most stations (table 8), but were most abundant above Nez Perce Creek, where the best spawning gravel was present. Rainbow trout young-of-the-year were most abundant in the middle section of the Firehole River around Midway Geyser. In shallow sections of stream with fast riffles, such as Station F, the number of Age Class 0 rainbow exceeded the number of Age Class 0 brown trout. Rainbow trout were not as abundant as brown trout in stream sections with a large inflow of warm water from geysers or hot springs. Gradient, however, was greater in sections where rainbows were abundant and could have influenced the numbers of rainbow trout as much as could thermal water inflow.

Madison River

Our fish population information in the Madison River was limited to that collected by the electric seine; this represented only a small percentage of the total population. Brown trout was the most abundant species in the Madison River, although rainbows were more common in the Madison than in the Firehole (table 6). Age Class 0 brown (ages determined from table 7) and small rainbow were collected at all stations but were most abundant in shallow water riffles of moderate gradient. The total number of catchable-size trout and whitefish collected at the seven stations per mile of stream was: brown, 271; rainbow, 21; and whitefish, 72.

The Madison River meanders in open meadow areas of low gradient, and deep (6 to 10 feet) holes are washed out under the banks. These areas often harbored catchable-size browns and rainbows. Large whitefish were collected most commonly in fast, deep (3-10 feet) water in the middle of the stream. Brown trout were most numerous in sections of the stream with abundant rooted aquatic plants. Rainbows were most numerous on fast riffles with a small amount of cover such as occasional boulders or logs. Many large whitefish and brown trout were collected or observed in deep holes in the lower section of the river. Young-of-the-year whitefish were collected downstream from the highway bridge (Station M). Sculpins and longnose dace were common on all sections of the stream, but were most abundant on fast, shallow riffles and were associated with Age Class 0 brown and rainbow trout.

GROWTH RATES OF WILD FISH

Firehole River

Brown trout in the Firehole River were growing rapidly during all years of the investiga-

Table 6.--Fish population data collected on Firehole and Madison Rivers, September 3-13, 1957. Numbers of fish per mile of stream at Stations A and B are population estimates as determined by the mark-and-recovery technique. Numbers of fish at Stations C to P represent the number of fish collected per mile by electric shocking samples which probably represent less than ten percent[1] of total population.

Location and species	Total length in inches																			Total No.
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Firehole River																					
Station A																					
Brown	1,754	4,610	1,044	176	317	317	129	82	47	47	59	47	23	47	47	0	0	0	0	0	8,746
Rainbow	0	0	0	0	0	0	0	23	0	0	0	12	0	0	0	0	0	0	0	0	35
Station B																					
Brown	622	7,226	4,551	1,443	481	94	176	82	35	0	0	59	0	0	59	23	47	23	59	0	14,980
Station C																					
Brown	70	933	3,467	2,658	405	53	123	88	88	0	88	35	35	35	0	0	0	70	35	0	8,183
Rainbow	0	0	0	176	141	0	0	88	0	0	0	0	0	0	0	0	0	0	0	0	405
Station D																					
Brown	0	0	28	56	36	20	4	8	8	0	12	8	4	0	0	8	0	0	0	0	192
Rainbow	0	20	76	96	44	44	8	4	12	8	0	4	0	0	4	0	0	0	0	0	320
Station E																					
Brown	0	44	70	53	0	9	0	0	9	0	0	0	0	0	9	0	0	0	0	0	194
Rainbow	0	0	9	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35
Station F																					
Brown	0	18	9	18	0	9	0	0	0	9	0	9	0	9	0	0	0	0	0	0	81
Rainbow	9	26	26	18	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	114
Station G																					
Brown	0	0	0	0	26	0	9	9	9	18	9	9	18	0	18	9	0	0	0	0	134
Rainbow	0	0	0	0	18	18	0	18	9	9	0	0	0	0	0	0	0	0	0	0	72
Station H																					
Brown	0	5	6	10	2	4	7	5	6	9	2	4	1	2	0	0	0	0	0	0	63
Rainbow	0	0	3	2	0	3	2	0	2	0	3	0	0	0	0	0	0	0	0	0	15
Station I																					
Brown	0	0	40	20	10	30	10	30	0	10	10	10	20	0	10	10	0	10	0	0	220
Rainbow	0	10	40	10	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	80
Madison River																					
Station J																					
Brown	0	14	28	7	7	21	14	21	0	0	0	0	0	0	0	0	0	0	0	0	140
Rainbow	0	0	42	7	0	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	63
Station K																					
Brown	7	36	30	5	3	10	21	6	4	2	5	8	9	9	3	3	2	2	0	0	165
Rainbow	7	10	5	1	3	4	1	1	0	0	0	0	0	1	0	0	0	0	0	0	33
Whitefish	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2
Grayling	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Station L																					
Brown	13	58	24	5	6	4	5	2	2	2	2	0	0	5	2	1	3	1	0	0	135
Rainbow	12	9	7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Whitefish	0	0	0	0	0	0	0	0	0	4	0	1	0	0	1	1	0	0	0	0	7
Station M																					
Brown	38	82	28	1	0	5	1	2	5	2	2	2	3	1	3	2	3	1	0	1	182
Rainbow	14	14	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	32
Whitefish	0	0	3	0	0	0	2	0	4	2	1	3	7	4	1	2	1	0	0	0	31
Station N																					
Brown	4	122	233	28	5	5	9	13	7	2	2	0	1	2	9	10	2	2	0	0	456
Rainbow	28	86	35	2	1	0	1	0	1	3	1	1	0	1	1	0	0	0	0	0	161
Whitefish	0	17	12	1	0	0	0	0	0	0	0	0	2	3	0	3	0	0	0	0	38
Station O																					
Brown	0	28	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76
Rainbow	0	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Whitefish	0	0	4	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Station P																					
Brown	2	26	58	54	4	0	2	4	4	2	2	0	2	0	0	0	2	4	0	0	166
Rainbow	10	48	90	66	14	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	230
Whitefish	0	0	10	18	4	0	2	0	2	4	6	2	6	2	4	0	0	0	0	0	60

[1] This percentage was estimated by observations of fish stunned by electric current but not captured, and from the fact that only part of stream width could be sampled at all stations.

Table 7.--Distribution of age classes of brown trout by inch groups in the Firehole and Madison Rivers. N denotes number of fish and P denotes percentage within each inch group.

Inch group	Age Class											
	0		I		II		III		IV		V	
	N	P	N	P	N	P	N	P	N	P	N	P
Firehole River												
2.0- 3.9	5	100										
4.0- 4.9	16	100										
5.0- 5.9	11	100										
6.0- 6.9	1	50	1	50.0								
7.0- 7.9			7	100.0								
8.0- 8.9			10	76.9	3	23.1						
9.0- 9.9			2	15.4	11	84.6						
10.0-10.9			1	14.3	6	85.7						
11.0-11.9			1	7.1	12	85.7	1	7.1				
12.0-12.9					9	75.0	3	25.0				
13.0-13.9					3	13.6	18	81.8	1	4.5		
14.0-14.9							12	92.3	1	7.7		
15.0-15.9							8	72.7	3	27.3		
16.0-16.9							4	50.0	4	50.0		
17.0-17.9									1	100.0		
18.0-18.9											1	100.0
19.0-19.9											1	100.0
Total	33		22		44		46		10		2	
Madison River												
2.0- 3.9	5	100										
4.0- 4.9	16	100										
5.0- 5.9	12	100										
6.0- 6.9	1	50	1	50.0								
7.0- 7.9			8	100.0								
8.0- 8.9			5	83.3	1	16.6						
9.0- 9.9			4	40.0	6	60.0						
10.0-10.9					5	100.0						
11.0-11.9					7	100.0						
12.0-12.9					5	82.3	1	16.6				
13.0-13.9					5	38.5	8	61.5				
14.0-14.9					3	37.5	5	62.5				
15.0-15.9							9	75.0	3	25.0		
16.0-16.9							4	44.4	5	55.6		
17.0-17.9									2	66.6	1	33.3
18.0-18.9											2	100.0
Total	34		18		32		27		10		3	

Table 8.--Numbers of brown trout per mile of stream in different age classes on the Firehole and Madison Rivers. Data for Stations A and B represent actual population estimates, while data from Stations C through P represent samples collected by electrical shocker. N denotes number and P denotes percentage of total number.

Station	Age Class												Total
	0		I		II		III		IV		V		
	N	P	N	P	N	P	N	P	N	P	N	P	
Firehole River													
A	7,743	88.5	598	6.8	230	2.6	135	1.5	40	0.5	0		8,746
B	14,082	94.0	375	4.6	248	3.0	106	1.3	14	0.2	105	1.3	8,178
C	7,330	89.6	488	3.3	148	1.0	78	0.5	55	0.3	129	0.9	14,980
D	102	52.8	43	22.3	25	12.9	14	7.3	9	4.7	0		193
E	167	86.5	10	5.2	8	4.1	4	2.1	4	2.1	0		193
F	45	55.6	10	12.3	8	9.9	14	17.3	4	4.9	0		81
G	13	9.8	23	17.4	41	31.1	35	26.5	20	15.2	0		132
H	22	35.5	13	21.0	19	30.6	7	11.3	1	1.6	0		62
I	65	28.9	54	24.0	43	19.1	35	15.6	18	8.0	10	4.4	225
Total	29,569	90.2	1,614	4.9	770	2.3	428	1.3	165	0.5	244	0.7	32,790
Madison River													
J	52	37.4	44	31.7	18	12.9	8	5.8	7	5.0	10	7.2	139
K	79	49.1	31	19.2	20	12.4	20	12.4	6	3.7	5	3.1	161
L	103	76.9	12	9.0	7	5.2	5	3.7	3	2.2	4	3.0	134
M	149	82.3	7	3.9	12	6.6	5	2.8	3	1.7	5	2.8	181
N	389	85.3	20	4.4	20	4.4	7	1.5	13	2.9	7	1.5	456
O	76	100	0		0		0		0		0		76
P	142	85.5	5	3.0	11	6.6	2	1.2	0		6	3.6	166
Total	990	75.4	119	9.1	88	6.7	47	3.6	32	2.4	37	2.8	1,313

tion (table 9) and were reaching catchable size by June of their second year. The mean total calculated lengths, in inches, at the end of each year's growth from 1953 to 1957 were: I, 4.7; II, 9.8; III, 13.8; IV, 16.0; V, 18.7; and VI, 21.4. The mean annual growth increments attained by fish of different ages from 1948 to 1956 did not show any consistent changes by calendar year of growth (table 10).

Rainbow trout young-of-the-year were growing more rapidly than the brown trout while the older age classes were growing more slowly (table 9). The growth rates did not fluctuate greatly among different calendar years (table 10).

Madison River

Both the rainbow and brown trout in the Madison River were growing at about the same rate as in the Firehole (table 11). No definite differences in growth rates were found among various calendar years (table 12).

A sample of 36 mountain whitefish, collected during 1956 and 1957, showed that this species was reaching the following mean lengths, in inches, at each year of life: I, 5.1; II, 8.9; III, 12.0; IV, 13.7; V, 15.3; and VI, 16.9 (table 13). Sigler (1951) summarized the studies on growth rates of mountain whitefish for this region; the Madison River fish were growing more rapidly than any of the stream populations mentioned.

AGE COMPOSITION OF CATCH

The catch of brown trout in the Madison River from 1953 to 1957 was composed principally of fish in their third and fourth years of life in the stream (table 14). The catch of brown trout in the Firehole generally included more fish in their second year (Age Class I) than did the Madison. Only 7.7 percent of the catch in the Madison and 6.2 percent in the Firehole were older than Age Class III.

More rainbow trout were caught in their second and third year (Age Class I and II) than were brown trout in both the Madison and Firehole Rivers. The oldest rainbows in the catch were Age Class IV. The catch of whitefish in the Madison in 1956 and 1957 was distributed among age classes as follows: II, 8; III, 11; IV, 9; V, 5; and VI, 3. Whitefish did not reach the creel until their third year and the catch was made up of more fish of the older age classes than was the case with brown or rainbow trout.

RATE OF EXPLOITATION OF WILD FISH

The rate of exploitation of brown trout by angling has always been inherently low in streams where detailed studies have been made (Schuck, 1948; Allen, 1951; Cooper, 1952). In the Madison and Firehole Rivers, the catch of brown trout has been influenced by changing fishing pressure, but there has been no evidence of overfishing on the population. There have been some complaints that the Madison does not now yield as many large browns as it formerly did. We cannot compare fishing pressure prior to 1953 with our present data, but it has undoubtedly increased, since the number of visitors to Yellowstone National Park has increased from 581,761 in 1941, the largest pre-war year, to 1,368,515 in 1955. This increased fishing pressure, possibly over 100 percent, may have reduced the number of large trout. Another possible cause for the small number of large browns is the fact that the present fishing season (May 30-September 30) closes too soon. Undoubtedly, many of those large browns were caught in the late fall on a spawning migration. Brown and Kamp (1942) mentioned October 9, 1936, as being one month prior to the spawning season in the Madison River; thus, it is possible that if these large brown trout still migrate up the Madison, they may do so after the present fishing season is closed. It is also possible that the "fly fishing only" regulation that began in 1950 restricted the catch of large brown trout.

From our population estimates of the Firehole in September, 1957, there was a minimum of 7,620 catchable-size brown trout left in the population after the 1957 fishing season was essentially completed. Since only 3,467 were caught, and because most of the surviving smaller trout grew large enough to enter the fishery in 1958, we believe that more brown trout could be caught without depleting the population. Our calculations show a maximum rate of 35 percent exploitation and it was probably closer to 15 percent since our population figures from the lower Firehole and the entire Madison

Table 9.--Mean calculated total lengths, in inches, at end of each year of life of 482 brown and 198 rainbow trout in Firehole River. All fish were collected by angling.

Species and year collected	Number of fish	Length at end of year					
		I	II	III	IV	V	VI
Brown trout							
1953	26	4.6	9.2	12.6	15.3		
1954	129	5.0	10.1	14.8	16.7		
1955	81	5.3	11.1	14.9	16.9	18.5	
1956	135	4.7	10.4	13.9	16.6	19.0	21.4
1957	111	4.1	8.4	12.7	14.9	18.5	
Total number	482						
Average length		4.7	9.8	13.8	16.0	18.7	21.4
Rainbow trout							
1954	49	5.5	9.2	13.3	15.6		
1955	39	5.0	9.2	12.4			
1956	63	5.5	9.5	12.7			
1957	47	5.1	8.9	13.1			
Total number	198						
Average length		5.3	9.2	12.9	15.6		

Table 10.--Mean calculated growth increments of all age classes of brown and rainbow trout in the Firehole River by calendar year of growth. Number of fish in parentheses. Means are weighted by the number of fish in different age classes.

Year of growth and species	Year in life of fish				
	1	2	3	4	5
Brown trout					
1949	4.3 (1)				
1950	5.2 (10)	3.7 (1)			
1951	5.3 (31)	5.9 (5)	4.6 (1)		
1952	4.4 (97)	5.3 (31)	2.8 (5)	2.6 (1)	
1953	5.4 (111)	5.5 (77)	3.9 (26)	2.6 (5)	
1954	4.7 (119)	5.7 (66)	3.8 (19)	2.8 (4)	
1955	4.5 (100)	4.8 (91)	3.3 (26)	3.3 (9)	4.1 (1)
1956	4.2 (18)	4.1 (34)	4.1 (46)	2.0 (11)	
Weighted mean	4.79 (487)	5.16 (305)	3.79 (123)	2.62 (30)	4.1 (1)
Rainbow trout					
1950	3.8 (3)				
1951	4.2 (6)	2.9 (3)			
1952	5.0 (25)	5.3 (6)	4.7 (3)		
1953	5.8 (40)	4.6 (25)	4.3 (6)	3.2 (3)	
1954	5.3 (46)	4.0 (23)	1.7 (2)		
1955	5.3 (63)	4.2 (26)	3.6 (6)		
1956	5.9 (15)	4.3 (26)	4.3 (6)		
Weighted mean	5.35 (198)	4.30 (109)	4.07 (23)	3.2 (3)	

Table 11.--Mean calculated total lengths, in inches, at the end of each year's growth for 432 wild brown trout and 125 rainbow trout in Madison River. All fish were collected by angling.

Species and year collected	Number of fish	Year of growth					
		I	II	III	IV	V	VI
Brown trout							
1953	17	4.6	10.3	13.2			
1954	161	4.3	10.3	14.1	16.6	18.8	20.2
1955	58	4.6	10.4	14.1	16.1		
1956	106	4.1	8.9	13.4	16.0		
1957	90	3.7	9.7	12.7	15.7	17.6	21.5
Total number	432						
Mean lengths		4.3	9.9	13.5	16.1	18.2	20.9
Rainbow trout							
1954	36	5.1	9.9	13.6	15.5		
1955	24	5.0	9.4	13.7	15.7		
1956	25	4.5	9.4	14.7	18.1		
1957	40	5.3	9.6	13.9			
Total number	125						
Mean lengths		5.0	9.6	14.0	16.4		

Table 12.--Mean calculated growth increments, in inches, of all age classes of brown and rainbow trout in the Madison River by calendar year of growth. Numbers of fish are in parentheses. Means are weighted by the number of fish in different age classes.

Year of growth and species	Year in life of fish											
	1		2		3		4		5		6	
Brown trout												
1948	4.1	(1)										
1949	5.5	(5)	4.1	(1)								
1950	4.9	(20)	5.2	(5)	4.8	(1)						
1951	4.1	(57)	5.4	(20)	3.6	(5)	2.8	(1)				
1952	4.3	(108)	5.9	(57)	3.2	(20)	2.6	(5)	2.3	(1)		
1953	4.5	(96)	5.8	(106)	4.2	(52)	2.8	(10)	2.1	(5)	2.1	(1)
1954	3.9	(66)	5.7	(79)	4.6	(27)	2.7	(3)				
1955	3.8	(61)	4.7	(64)	3.9	(48)	3.4	(4)	1.9	(1)		
1956	3.9	(18)	5.0	(27)	3.9	(27)	3.5	(10)			2.6	(1)
Weighted mean	4.21	(432)	5.50	(363)	4.01	(180)	3.04	(33)	2.10	(7)	2.35	(2)
Rainbow trout												
1950	3.9	(6)										
1951	5.2	(17)	4.6	(6)								
1952	4.4	(8)	5.5	(17)	3.3	(6)						
1953	5.2	(34)	4.6	(8)	4.5	(17)	3.7	(6)				
1954	4.6	(18)	4.2	(24)	5.4	(2)	2.9	(3)				
1955	4.8	(18)	5.5	(14)	5.6	(9)						
1956	5.9	(23)	5.1	(9)	4.6	(8)						
Weighted mean	5.07	(124)	4.89	(78)	4.63	(42)	3.43	(9)				

River were grossly underestimated. Cooper (1952) recorded a 25-percent rate of exploitation in the Pigeon River, Michigan. Allen (1951) found that anglers caught 27 percent of the catchable-size fish present at the beginning of the season in the Horokiwi, New Zealand. Schuck found that anglers caught from 15 to 28 percent of the available crop in Crystal Creek, New York. Hobbs (1948, as quoted from Allen, 1951) reviewed several papers on brown trout and found that an average of 13.8 percent were harvested. Brown trout grow fast enough to enter the catch by June in their second year, and there were, at a minimum 40,000 young-of-the-year brown trout present in September, 1957. Although overwintering mortality will reduce this population considerably, there will be adequate numbers to support a large fishery. Allen (1951) found in the Horokiwi stream in New Zealand that even under a relatively heavy fishing pressure, angling mortality on brown trout seldom accounted for more than one-third of the natural mortality. Cooper (1953a) found that angling never made up over 17 percent of the total mortality from the first to the second year of life for brown trout in the Pigeon River. Needham (1949) found natural mortality in brown trout populations much higher than angling mortality.

The catch of wild rainbow in both the Firehole and the Madison did not vary greatly from 1954 to 1957. The range in the catch on the Madison was from 1,040 to 1,301 fish while the range on the Firehole was from 1,955 to 2,540. There is little doubt that it is possible to overfish resident rainbow trout populations in streams since so few large self-sustaining resident populations exist in the United States today in spite of the large number of rainbows planted.

There is evidence from our population studies and creel census that overexploitation of rainbow trout probably existed in both the Madison and Firehole Rivers. The catch of rainbows was predominantly Age Class I fish which had not had a chance to spawn. Leach (1939) stated that 15 to 20 percent of female rainbow trout mature in their second year and 60 percent in the third year. Most males mature in their second year. Our data from the Madison and Firehole Rivers show a sex ratio in the catch of Age II and older fish of 51.4 percent males to 48.6 females during 1956 and 1957. If we combine our age compositions of the catch data with our total catch, we find that there were 240 Age Class II and 213 Age Class III rainbow trout caught on the Madison in 1957. If 48.6 percent of these were females and only 15 to 25 percent of the Age Class II and 60 percent of the Age Class III fish were sexually mature, we can calculate that anglers caught about 79 female spawners. Our population data in September, 1957, showed less than 50 females left in Age Class II and III. Thus, our total population of spawning females was less than an estimated 129 fish. A comparable estimate of the number of female brown trout spawners would be over 2,000. In September, 1957, we counted 900 Age Class 0 browns and 509 Age Class 0 rainbows on the Madison River. Thus, it appears that the survival rate in Age Class 0 fish up to September of the first year is higher for rainbows than browns. The lower number of older rainbows may be attributed to higher exploitation of the spawning population rather than a possible lower survival rate of rainbows.

The whitefish catch increased during periods of heavy fishing pressure, but there is no evidence that whitefish were being fished heavily. They are not considered as palatable as trout during the summer and are not as popular to catch. They were also present in deeper and more turbulent water than browns or rainbows which makes them more difficult to catch, especially for the inexperienced angler.

Brook trout were abundant in certain sections of the Firehole and Gibbon, but their small size makes them unattractive to most anglers and they are not fished heavily enough. Heavier exploitation of this species might increase their average size.

INFLUENCE OF PLANTING ON WILD FISH

There has been some disagreement in the literature on the subject of the influence of hatchery fish on wild fish populations. Hazzard and Shetter (1939) stated that the increased fishing pressure commonly associated with planting brook, brown, and rainbow trout increased the harvest of wild fish. Chamberlain (1943) found that planted fish served as a buffer and prevented overexploitation of wild rainbows. Cooper (1952)

Table 13. Calculated total lengths, in inches, by age classes, a at the end of each year's growth for 36 whitefish in the Madison River. Collected in 1956 and 1957.

Age Class	Number of fish	Average calculated total lengths at each annulus					
		1	2	3	4	5	6
II	8	6.9	8.7				
III	11	4.7	9.2	12.4			
IV	9	4.4	8.2	10.9	12.9		
V	5	4.7	8.5	11.6	13.2	14.6	
VI	3	4.7	9.8	13.0	15.1	16.0	16.9
Total number 36							
Mean lengths		5.1	8.9	12.0	13.7	15.3	16.9
Mean annual increment		5.1	3.7	3.1	1.7	1.6	1.6

found that planting large numbers of rainbows apparently had no effect on wild fish populations. Holloway and Chamberlain (1942) found that planting large rainbow trout for the creel exerted less pressure on the wild trout populations than did fingerling plantings since there was no competition for food as there is during the growth period for fingerling fish. Neither wild brown nor rainbow trout in the Madison and Firehole Rivers seemed to be adversely influenced by the plantings of large numbers of fish in 1954 and 1955. The catch of brown trout increased due to heavier fishing pressure, but the wild rainbow catch was remarkably stable during the study (fig.3). A heavier harvest of brown trout was not overexploiting the population. Growth rates did not change on either wild brown or wild rainbow trout when no stocking was carried out in 1956 and 1957.

ADULT FISH PLANTING EXPERIMENTS

Many agencies periodically determine the return of planted catchable-size hatchery fish to evaluate their stocking programs. Such management research is wise because of changing environments and fishing pressure. Frequently it is not possible to mark every planted fish and to observe the catch of each angler, and certain problems in carrying out such studies are frequently overlooked. The original research plan on this investigation called for the marking by fin clipping of approximately 40 percent of the fish planted and to assume that the marked-unmarked ratio would be the same in the catch as in the plants. Fortunately, scale samples were taken from all fish checked by creel clerks. As illustrated earlier in this paper, adult planted hatchery fish can be easily distinguished from wild fish by the pattern of circuli. Chapman (1958) tested the use of scale pattern characteristics to segregate hatchery steelhead from wild stock and reached an accuracy of almost 100 percent. Our recovery results would have been greatly different from the true results if we had used fin clips to estimate recovery rates rather than the scale sample method (table 15). The hatchery life of a fish is permanently marked on the scale, and it is suggested that this method be used unless it is possible to mark every hatchery fish planted.

MANAGEMENT

The fish management policy of the National Park Service, dated June 17, 1954, states that native fish species should be encouraged and that the stocking of catchable-size fish should be avoided if possible. The three principal trouts in this stream system, the brown, rainbow, and brook, are all introduced species and our management must only consider these well-established species. We have shown that the planting of fingerling rainbow and brown trout does not contribute to the catch and such a planting program should be avoided in the future.

Table 14.--Number of fish of different ages in catch by years of wild brown and rainbow trouts in Madison and Firehole Rivers. Percentages in parentheses.

Stream, species, and year	Number of fish	Age Class					
		I	II	III	IV	V	VI
Madison River							
Brown trout							
1953	17	2	5	10			
1954	161	17	79	49	10	5	1
1955	58	2	31	23	2		
1956	106	30	37	38	1		
1957	82	10	31	27	10	3	1
Total	424	61(14.4)	183(43.2)	147(34.7)	23(5.4)	8(1.9)	2(0.4)
Rainbow trout							
1954	36	10	6	14	6		
1955	31	8	16	4	3		
1956	25	9	6	9	1		
1957	39	22	9	8	0		
Total	131	49(37.4)	37(28.3)	35(26.7)	10(7.6)		
Firehole River							
Brown trout							
1953	26	20	5		1		
1954	129	45	58	22	4		
1955	81	28	40	10	3		
1956	135	66	45	15	7	1	
1957	111	18	34	46	11	2	1
Total	482	177(36.7)	182(37.8)	93(19.3)	26(5.4)	3(0.6)	1(0.2)
Rainbow trout							
1953	3	2	1				
1954	49	17	23	6	3		
1955	39	20	17	2			
1956	63	37	20	6			
1957	47	15	26	6			
Total	201	91(45.3)	87(43.3)	20(10.0)	3(1.4)		

Table 15.--Comparison of computations of number of hatchery rainbow trout caught by anglers by using fin-clipped fish and by using scale samples.

	1954	1955
Number of fish planted	25,006	24,792
Number of planted fish fin-clipped	10,003	8,000
Ratio of fin-clipped to non-fin-clipped fish in planting	1:2.5	1:3.09
Ratio of fin-clipped to non-fin-clipped fish in catch	1:1.9	1:1.57
Number of hatchery fish caught, calculation by fin-clipping method	11,003	24,720
Number of hatchery fish caught, calculation by scale method	8,300	12,128

The planting of catchable-size rainbow trout does create fishing with no detrimental influences on the wild trout population, although such a program is contrary to Park Service policy. Therefore, future management should be concerned with retaining the excellent wild brown trout population and possibly with encouraging the wild rainbow trout.

The brown trout populations in both the Madison and Firehole Rivers are well distributed among the different age classes, and a greater harvest would be possible without overexploiting the fishery. The "fly-fishing only" regulation interferes with the harvest of large browns and could be removed. No additional restrictions are necessary.

The wild rainbow population may be exploited under the present system and a larger size limit on this species might increase the spawning population. Such a management method was used in Michigan on the North Branch of the Au Sable (Shetter, Whalls, and Corbett, 1954). This type of management should only be instituted after several years of special investigation, particularly on the mortality rates of wild rainbow trout. The present wild rainbow catch has remained stable in both the Madison and Firehole and there is no reason to believe that the rainbow population will decline due to heavy pressure, since it has already withstood extremely heavy pressure when catchable-size rainbows were planted. Another consideration in the management of these streams is that the present trout fishing in both the Madison and Firehole demands expert angling, especially in the late summer, while a catchable-size rainbow stocking program gives the novice fisherman a chance to fill his creel.

SUMMARY

The Madison River system in Yellowstone National Park consists of the Firehole and Gibbon Rivers which join to form the Madison; it has 81 miles of stream in the Park. Investigations on these streams were carried out from 1953 to 1957 to determine the value of existing stocking policies and to suggest management procedures for an expected increased use of these streams. The past management of these streams had involved the planting of rainbow

and brown trout fingerlings and rainbow adults and the regulation of fishing dates and catch limits.

The Firehole, Madison, and Gibbon Rivers are described generally from physical, chemical and biological standpoints. Hot springs and geysers entering the Firehole River do not appear to restrict the number of brown and rainbow trout.

Stocking experiments were designed to test the value of fingerling and adult trout stocking. Of the 48,216 rainbow fingerlings planted, only 78 (0.16 percent) were caught; none of the 29,249 brown trout fingerlings planted were found in the catch. In adult stocking experiments about 40 percent of planted fish, 25,006 in 1954 and 24,792 in 1955, were marked by fin clipping. From the 1954 plants 8,300 were caught; from the 1955 plants 12,128 were caught. It was originally assumed that the ratio of marked to unmarked fish in the plantings would persist in the catch, but a different ratio was found. Examination of scales showed that hatchery fish could be easily distinguished from wild fish.

The number of fishing trips on the Madison River system was: 1953, 19,504; 1954, 27,233; 1955, 23,477; 1956, 24,293; and 1957, 25,599 (not including Gibbon). Fishing pressure increased when adult rainbows were planted in the Madison and Gibbon Rivers.

Wild rainbow catches in the Madison and Firehole Rivers have remained relatively stable in spite of the large number of fingerlings and adults planted. Wild brown trout catches increased with heavier fishing pressure due to adult rainbow stocking on the Madison, but not on the Firehole.

Fish population studies were conducted in September, 1957, with an electric shocker in the Firehole and Madison Rivers. Age Class 0 and catchable-size brown trout were very abundant; Age Class 0 and catchable-size rainbows were common in both streams. Whitefish were common in the Madison River.

Wild adult brown and rainbow trout in both the Madison and Firehole Rivers were growing rapidly at about the same rate. Brown trout were eight inches long by June of their second year. Whitefish were also growing rapidly. No differences in growth rates of wild fish could be discerned among different calendar years when stocking rates were changed. The catch of brown trout in both the Firehole and Madison was composed principally of fish in their third and fourth years, while rainbow trout were most commonly caught in their second and third years. The whitefish catch represented older age classes.

There was no evidence of heavy exploitation of brown trout, but there was some evidence of high exploitation of rainbow trout.

Neither wild brown nor rainbow trout populations appeared to be adversely influenced by heavy planting of fingerling brown and rainbow trout or by adult rainbows.

Faulty conclusions may result from marking experiments when only about 40 percent of the adults are marked by fin clipping. In such studies it would be most desirable either to mark all planted fish or use the scale method to calculate returns.

Future management in these streams should emphasize the use of wild brown and rainbow trout.

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